Rochester Institute of Technology
RIT Scholar Works

Theses | Thesis/Dissertation Collections

5-1-1994

A Study on understanding the use of a process color-based color communication systems to print synthetic colors accurately and consistently

Michael Gerald Go Lim

5-1-1994

A Study on understanding the use of a process color-based color communication systems to print synthetic colors accurately and consistently

Michael Gerald Lim

A Study on Understanding the Use of Process Color-Based Color Communication Systems To Print Synthetic Colors Accurately and Consistently

by

Michael Gerald Go Lim

A project thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Printing Management and Sciences in the College of Imaging Arts and Sciences of the Rochester Institute of Technology

May 1994

Thesis Advisor: Professor Robert Chung

School of Printing Management and Sciences
Rochester Institute of Technology
Rochester, New York

Certificate of Approval

Master's Thesis

This is to certify that the Master's Thesis of

Michael Gerald Go Lim
name of student

With a major in Graphic Arts Publishing
has been approved by the Thesis Committee as satisfactory
for the thesis requirement for the Master of Science degree
at the convocation of

May, 1994
date

Thesis Committee:

Robert Chung
Thesis Advisor

Marie Freckleton
Graduate Program Coordinator

George Ryan
Director or Designate

Title of thesis A Study on Understanding the Use of Process Color-Based Color Communication Systems To Print Synthetic Colors Accurately and Consistently

I, Michael Gerald Go Lim , hereby **grant permission** to the Wallace Memorial Library of R.I.T. to reproduce my thesis in whole or in part. Any reproduction will not be for commercial use or profit.

Date ______________________________

Acknowledgments

I wish to thank Robert Chung, for his invaluable guidance, patience, and encouragement in the course of completing this study. I would also like to extend my appreciation to Cliff Frazier, Marie Freckleton, and Franz Sigg for the valuable insights they have shared with me. I am certain that the creativity, the zeal, the dedication, and the pragmatism that I have learned to appreciate from them, will stay me through life after graduate school (which has been very satisfying), with all its challenges and opportunities.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The study is intended to provide a better understanding on the use of process color-based color communication systems such as those provided by Focoltone, Trumatch, and Pantone, in order to print synthetic colors as accurately and as consistently as possible. Using Focoltone's system, an investigation was done on the materials and documentation, as provided by the Focoltone kit.

The available information, as provided by Focoltone, was supplemented by the author's interpretation of Focoltone's specifications. From the author's understanding of Focoltone specifications, a set of procedures were outlined that would contribute towards the accurate and consistent reproduction of synthetic colors on a press run.

The study concludes that the use of standard film dots, as specified by Focoltone, to reproduce the reference colors on the swatchbook, is questionable because the dot gain characteristics of press run(s) used to print Focoltone's swatchbooks differ significantly from that of industry average values obtained from FIPP. Moreover, as each production press would exhibit its own dot gain characteristics, the use of a standard film dot in the printing process would not contribute to an accurate reproduction of color.

Instead, the study recommends that procedures have to be established that:

1. Enable the conversion of standard film dot area specifications into custom film dot specifications to suit the particular press run's dot gain

characteristics. This procedure requires the availability of the plate/press curve of the printing process used to print the swatchbook, and that of the production press, as established in a fingerprint press run.

2. Ensure that the graphic reproduction process, from film to plate to press, is implemented in standardized conditions and manner, and that process control of SID be established, so that deviations from desired SID and dot gain are minimized.

This way, the synthetic colors, using process color-based color communication systems, can be as printed as accurately, with reference to the reference color swatches, and as consistently throughout the press run.

INTRODUCTION

PURPOSE OF THE STUDY

The Pantone Matching System provides a set of colors that print buyers and designers refer to in specifying colors to printers. Although it is the most popular print color communication system in use, it is based on the use of spot colors. Because spot color-based color communication systems have some disadvantages, new color communications based on process color are being offered by Focoltone, Trumatch, and Pantone as well.

Print buyers, designers, and printers would be interested in knowing whether the use of a process color-based color communication system is viable as an alternative to the Pantone Matching System.

This study seeks to provide a framework for understanding the nature of process color-based color communication systems. This understanding should enable print designers and buyers to properly evaluate the use of these systems with respect to their needs. Likewise, it should enable printers to properly implement procedures that allow specified colors to be reproduced as accurately and as consistently as possible.

DEFINITION OF TERMS

Synthetic color is color that is used generally in infographics and illustrations, notably cartoons, where there is no need to match memory colors (Hannaford, 153). Synthetic color contrasts with color as seen in nature, as exemplified by the features on a person's face, where there is a continuous shift in tones.

Process color printing usually refers to four-color printing, which is a way of printing color by overprinting a succession of tints from the four process colors–cyan, magenta, yellow, and black. Because each process color can be printed with a range of tints (from 1 to 99%), and because of the many combinations of tints that can be made from all four process colors, a wide (but limited) gamut of color can be achieved. However, this process requires all four process colors to be printed on paper before the final color is attained.

Spot color printing, on the other hand, requires a minimum of one impression of ink, in which the ink is premixed from a set of base colors in the manner that paint is usually mixed.

CONSIDERATIONS

Process color-based color communication systems consist of the use of color specifiers in the form on swatches printed on paper. The colors are defined in terms of the dot size of the component CMYK (cyan, magenta, yellow, and black) printers. When a specified color is to be printed, the corresponding tints (dot size) are output on four separation films. From these films, plates are exposed and used in a four-color lithographic press run, where color is reproduced on paper.

Advantages

To the print designer, process color -based systems have a distinct advantage over spot color-based systems when used to specify color. With the use of process color printing, the print designer is given the flexibility to use more synthetic colors in designs without being concerned that each additional color would have an incremental cost.

The spot color system limits designers in the number of colors to use in their designs. This is largely associated with the cost penalty for each additional color (McIlroy, 39). Each additional color would require a corresponding additional printing pass, and the associated labor, material, time, and overhead that comes with it. In contrast, using a system based on process color printing, all the colors reproducible under the four-color process can be selected by the designer.

To the print buyer and printer, process color-based systems could in many cases lead to lower costs in printing. Because four common inks are used, different print jobs can be gang-printed together. Furthermore, because the same inks are used in successive press runs, there is no press downtime to change inks in between press runs. Because printing resources are used more efficiently, printing costs may be lowered significantly.

Disadvantages

The designer has to realize that four-color process printing provides a limited color gamut, which restricts the designer from using many colors available in Pantone's spot color system (Streight, 170). Furthermore, metallic and fluorescent colors are without doubt beyond the range of process color printing.

To the printer, process color printing demands more quality control than spot color printing. It involves good control of process variables such as ink film thickness, dot gain, trapping, and ink-water balance (Field, "Process...", 75). Process control becomes imperative when synthetic colors are to be printed, as synthetic colors have a uniform tonal background. Variations in the printing process are more apparent in such a situation (Fink, 9).

In comparison, spot color printing is subject to less variability. As spot color is usually applied as a solid impression, color variability as contributed by dot gain does not exist. Since dot gain has the most influence on color variability (Leach, 30-32), color variability using spot colors would not be as pronounced as with using process colors.

Rationale for the Study

Notwithstanding its disadvantages, the use of process color-based color communication systems promises to enable decision-makers of color printing to lower some of the prohibitive costs of color printing. With the use of process color printing, the print designer is given the flexibility to use more synthetic colors, without being concerned that each additional color would have an incremental cost. However, the print designer has to be convinced that synthetic colors printed with process colors can be reproduced within acceptable limits of accuracy and consistency. Without the assurance, the designer would not be encouraged to use process color-based communication systems in specifying color.

Similarly, printers would be interested in knowing whether they can provide that assurance to the print buyer and designer. Therefore, it is important for the printer to first have a keen understanding of both the nature of process color-based communication systems and relate that to the capabilities and limitations of the lithographic process. This way, printers can identify the critical factors to consider in printing synthetic colors using the abovementioned processes and systems, in order to print synthetic colors as accurately and as consistently as possible.

II. REVIEW OF RELATED LITERATURE

APPROACHES TO CONTROLLING PROCESS COLOR PRINTING

Controlling process color printing is achieved in two ways. One is aimed at minimizing process variability at the start. The other involves process control, in which special-caused variations in color output are monitored and corrected.

The first approach, minimizing process variability, would involve the use of improved equipment and procedures such as the use of better dampening systems, segmented ink fountain blades, and tighter control of raw material quality.

The second approach involves the use of test images, quality control instruments, and control mechanisms, all applied towards achieving given quality specifications (Field "Process...", 75).

VARIABLES TO CONTROL IN PROCESS COLOR PRINTING

The following variables must be controlled to achieve consistent results in lithographic printing: dot gain, solid ink density, trapping, grey balance, and register.

Dot gain describes the change in dot area that occurs from the film to the final print. The following factors contribute to dot gain:

1. The transfer of image from the film to the plate
2. The transfer of image from the plate to the blanket
3. The transfer of image from the blanket to the paper

The blanket, the paper, and the ink (especially the viscosity) influence the dot gain that occurs between the plate and the blanket, and between the blanket and the paper.

Dot gain is expected in lithographic printing. However, it has to be controlled. If the amount of dot gain can be measured and expected, the dot size can be reduced to compensate for the dot gain that will occur when printing.

Solid ink density is important in reproducing color. However, changes in solid ink density have less influence on the appearance of the print than changes in dot gain (Leach, 30-32).

COLOR TOLERANCES AND VARIABILITY

Color tolerances are specified by the customer, establishing limits to the change allowed in a color reproduction knowing that it will still generate the intended visual responses from the viewer. Customers realize that tolerances are needed since the cost of reproduction will increase if tolerances are not allowed (Stamm, 157).

Color variability is the change in color that is attributed to the printing process, the materials involved, and the people involved. When a reproduction system is optimized, the variability should be contained within the tolerances (Stamm, 157-158).

Compton and Wilson (159), concludes in a study that variations of solid ink density and dot gain can be minimized when operators in an offset printing process were not allowed to alter press setting during a press run.

Hue Error and Grayness

The use of printing ink of different color properties, as described by hue error and grayness, results in color reproducing differently (Hunt, 575). The definition of these two properties are:

Hue error= (M-L)/(H-L) * 100
Grayness= L/H * 100

where for any of the three inks (cyan, magenta, yellow), H represents the highest, M the middle, and L the lowest density readings in terms of the red, green, and blue filters. An ink that does not have unwanted absorption would have zero values for hue error and grayness (Hunt, 570-571). For example, a pure cyan ink would only absorb red light, and not absorb green and blue light. Hence, it would only register a density reading only with the red filter.

Apparent Dot Area (ADA)

The apparent dot area is calculated using the Murray-Davies Equation, which includes optical and physical dot area:

$$\% \text{ ADA} = (1-10^{-D_t}) / (1-10^{-D_s}) * 100$$

where: D_t = Density of printed target tint minus paper density
D_s = Density of nearest solid patch minus paper density

III. METHODOLOGY

The objective of this study initially was to determine the accuracy and consistency of printing synthetic colors that are derived from process color-based color communications systems. Because the assumptions toward that inquiry was questionable and was discovered at a late stage, the subject of inquiry was modified to its present form.

Nevertheless, it was felt that process color-based color communication systems such as those provided by Focoltone, Trumatch, and Pantone, can be better understood, especially from the user's standpoint, instead of the swatchbook maker's standpoint.

In mistakenly assuming that the dot area specifications of the Focoltone swatchbook referred to paper dots, the author had felt certain that film dot area specifications were not adequate, due to the fact the process of reproducing the dot from film to paper would produce paper dots that vary in size from one press run to another. It was this predisposition to regard the paper dot area (which has more influence than the film dot area on the swatchbook color), instead of the film dot area, as the standard dot specified, that led to a misinterpretation of the Focoltone specifications.

But it was also this predisposition that led the author to redirect his inquiry. Thus, the inquiry was made so as to better understand process color-based color communication systems. Once these systems are understood firmly, they can be made useful for printers and print designers and buyers, instead of being a source of confusion and disappointment.

For the purposes of the study, only one process color-based color communication system was evaluated. Focoltone, Trumatch, and Pantone all share a common approach: that of specifying color in terms of film dot for the component CMYK process colors. These colors are presented in swatchbooks and color specifiers, which serve as the reference or target colors. These systems are intended for conventional lithographic four-color process printing on paper, both coated and uncoated.These systems differ mainly on the selection on colors they offer. Because these systems have many points of simlarity, only one system was chosen to evaluate process color-based color communication systems. The Focoltone system was arbitrarily chosen for this study.

The methodology begins with examining the swatchbook, the color specifier book, and the documentation, as supplied in the Focoltone kit. An X-Rite 418 densitometer, which has a status-T response, was used to obtain densitometric readings from the swatchbook. Solid ink density (SID) and apparent dot area readings were obtained.

Since the swatchbook was the only means of obtaining SID and apparent dot area data, a number of assumptions were made:

1. That the Focoltone swatchbook used in the study was representative of Focoltone swatchbooks in general, in terms of SID, dot gain, and color characteristics.
2. That the swatchbooks were printed in a state of statistical process control, where SID variations were in control.
3. That the swatchbooks were printed in standardized conditions, such that dot gain characteristics would be similar in all pages of the swatchbook.

SID values of the swatchbook were obtained from the solid patches of CMYK in the swatchbook. Values of paper dot area, were obtained by measuring the color swatches on the swatchbook that correspond to Focoltone colors having a single color tint. For example, in order to obtain the paper dot area of a 15% Cyan film tint, the cyan paper dot area of Focoltone 1011, which consists of a 15% Cyan film tint, was measured on the swatchbook.

Using the data obtained from the swatchbook, a critical examination of Focoltone's documentation was pursued. In the analysis, Focoltone specifications were defined more specifically, and an attempt to remove ambiguity was made.

With specifications clearly defined, procedures for preparing and implementing a press run are described, in the context of printing synthetic colors as accurately, with reference to swatchbook colors, and as consistently, throughout a press run, as possible.

IV. DISCUSSION

THE FOCOLTONE SYSTEM

As noted earlier, the color systems specify color in terms of the dot size on film. This point has to be emphasized because there are many factors that affect the final reproduction of the film dot on paper, and other factors besides dot size that determine the final color reproduced on paper.

According to Focoltone's introductory booklet, their system provides a visual standard, which is used as a reference when evaluating a printed color. This visual standard does not change. When the printing conditions are different from Focoltone's printing conditions, the film dot specifications can be changed. For example, Focoltone 4034 has a standard specification of 15% Magenta and 15% Yellow. If the printing condition is different, the specification could be changed to, for example, 14% Magenta and 13% Yellow.

Changing the film dot specifications is made possible by using a dot gain program. With information on the dot gain of the new printing condition and the Focoltone number, the new film dot specification can be obtained. The new film dot specification is used to produce films. Based on these films, the Focoltone colors are printed under the new printing condition. The result should be printed colors that are a close match to the reference from the swatchbooks.

However, the booklet mentions that Focoltone colors can be reproduced using the standard specifications on any normal rotary sheet fed press, using industry average solid ink density and dot gain values. Accordingly, a close match can be easily achieved by adjusting ink density levels and making normal press adjustments when needed.

In its manual, Focoltone mentions four factors that can cause color to shift:

1. Dot gain behavior of the process which is different from industry average dot gains, which Focoltone follows.
2. A considerable change in the pigmentation of one or more of the process inks.
3. A change in the paper stock from the type used in the swatchbook or specifier sheet
4. Changes in printing conditions such as temperature and density

Noteworthy points mentioned in the introductory booklet are:

1. That many different international sets of process inks, such as those adhering to American, British, and European standards, share color properties similar enough to each other. Such being the case, Focoltone has found printing from different ink sets to have a minor effect on causing color variation. Instead, Focoltone recommends the use of inks that have adequate pigment strength. Weaker strength inks need a thick application of ink, which results in higher dot gain.
2. That dot gain changes on different papers depend mainly on the smoothness of the paper stock. Slight differences in gloss would not cause significant color shifts.

Beyond these information, the introductory booklets does not explain in greater detail the principles and procedures behind not only reproducing accurately the swatchbook colors, but also reproducing them consistently from the start to the end of the press run. The following sections will examine the different procedures involved in the graphic reproduction process, and will examine Focoltone's system critically, in order to apply Focoltone's system towards reproducing color as accurately and as consistently as possible.

Understanding the Target Specifications

In order to adequately produce a product within specifications, it is important to have a standard to aim for, a knowledge of the conditions and characteristics of the process, and good control of the process. Similarly, in reproducing the Focoltone colors, one must understand the target specifications to use as a standard, a knowledge of the process conditions and characteristics of the production press run, and the means and procedures to control the variables necessary in achieving accuracy and consistency in color reproduction.

Focoltone's specifications for printing colors can be described as follows:

1. An ink set of adequate pigment strength, and which follows international (American, British, European) standards
2. Coated paper that does not differ significantly in gloss characteristics from paper used in the Focoltone swatchbook
3. The film dot area for the process colors
4. Solid ink density and dot gain based on industry averages
5. Screen frequency of 150 lpi
6. Printing sequence of Cyan-Magenta-Yellow-Black (CMYK)

Ink Trapping, although not mentioned, would be assumed to be have characteristics consistent with the operation of a conventional four-color lithographic press, with wet-on-wet printing.

The specifications given by Focoltone can be subject to varying interpretation by users. The specifications can be divided into two categories–material and process.

Material

The material specifications involve the ink set and the paper. Although the study focuses more on the process specifications, the material specifications need to be clarified. Since Focoltone does not provide a more specific description of the ink set and paper, the properties of the paper and the ink set are assumed to be based on the swatchbook.

Process

The process specifications that deserve closer examination are the solid ink density, the film dots, and the dot gain from film to paper.

Solid Ink Density

Solid ink density (SID), as measured from the solid patches of the four process colors in the swatchbook, are shown in Table 2. Focoltone vaguely describes the SID in terms of industry average values, which can assume different values. As shown also in Table 1, the SID values would vary significantly between GCA (Brehm, 32) and Flint (Flint, 4). Thus, it would be better to base SID targets on the SID values obtained from the swatchbook.

Table 1. Solid Ink Density (Status T)*,
Values From Different Sources

Color	Solid Ink Density		
	Swatchbook	GCA	Flint
Cyan	1.27	1.25	1.30-1.35
Magenta	1.25	1.30	1.40-1.45
Yellow	1.00	0.98	1.00-1.05
Black	1.60	1.65	1.65-1.75

*Values are not zeroed on paper.

Film Dot and Dot Gain

The dot gain, from film to paper, is also vaguely described by Focoltone as industry average. One set of industry values, as provided by FIPP (International Federation of the Periodical Press), is examined as to whether it can appropriately describe the dot gain from film to paper, for the Focoltone tints.

Table 2 shows the dot gain at 40%, 50%, 60%, 70%, 75%, and 85% tints as based on industry averages obtained from FIPP (9) and as obtained from the Focoltone swatchbook. From the large difference in dot gain values between the FIPP industry average and the Focoltone swatchbook, it can be said that the paper dot area on the swatchbook cannot correspond to a press run exhibiting industry average dot gain behavior.

If a press run with industry average dot gain values were used to print the aforementioned tints, the results would be paper dots which differ largely from the actual paper dots on the Focoltone swatchbook. These values are shown in Table 3. The graph in Figure 1 typifies the differing dot gain characteristics, as shown by the Focoltone plate/press curve differing from the two FIPP curves of Cyan.

Thus, a more appropriate approach would be to describe the dot gain behavior (of the press run used to print the Focoltone swatchbooks) in terms of actual dot gain, as observed from the swatchbooks printed. Since the paper dot area is actually the film dot area plus dot gain, dot gain can also be described in terms of both film dot area and paper dot area. Using film dot area and paper dot area values for the entire plate/press range (from 0 to 100 percent), a plate/press curve can be constructed. The plate/press curve, plotting film dot versus paper dot, aptly describes the dot gain behavior of the press run(s) used to print the Focoltone swatchbook.

Table 2. Comparison of Dot Gain Values*
Between Focoltone Swatchbook and FIPP Industry Average

Film Dot Area (%)	Dot Gain (%)		
	Swatchbook	FIPP	
		Positive Working Plates	Negative Working Plates
Cyan 40	9.1	18	25
50	7.9	19	24
70	7.1	16	21
75	7.0	14	19
80	6.1	12	16
Magenta 40	8.5	18	25
50	8.6	19	24
70	10.6	16	21
75	5.9	14	19
80	9.2	12	16
Yellow 40	8.9	18	25
50	10	19	24
70	10.7	16	21
75	13	14	19
80	10.9	12	16
Black 40	7.1	18	25
50	8.4	19	24
70	7.4	16	21
75	7.0	14	19
80	-	12	16

* Based on Murray-Davies Equation.

Table 3. Comparison of Paper Dot Areas As Based Upon Focoltone Swatchbook and FIPP Industry Average Dot Gain Values

Film Dot Area (%)		Paper Dot Area (%)		
		Swatchbook	FIPP	
			Positive Working Plates	Negative Working Plates
Cyan	40	49.1	58	65
	50	57.9	69	76
	70	77.1	86	91
	75	82.0	89	94
	80	86.1	92	96
Magenta	40	48.5	58	65
	50	58.6	69	76
	70	80.6	86	91
	75	85.9	89	94
	80	89.2	92	96
Yellow	40	48.9	58	65
	50	53.9	69	76
	70	80.7	86	91
	75	88.0	89	94
	80	90.9	92	96
Black	40	47.1	58	65
	50	58.4	69	76
	70	75.5	86	91
	75	80.4	89	94
	80	-	92	96

The use of a plate/press curve is more useful in specifying the reference colors. First, it directly relates film dot area to paper dot area. Secondly, it provides dot gain relationships across the entire tonal range. Since Focoltone regards as a constant reference the swatches, the paper dot area, not the film dot area, should be regarded as a constant specification, though it is not explicitly specified. When the film dot area and a corresponding plate/press curve are specified, in effect the paper dot area is specified as well.

Figure 1. Plate/Press Curve of Cyan,

Focoltone Swatchbook and FIPP (Positive and Negative Working Plates)

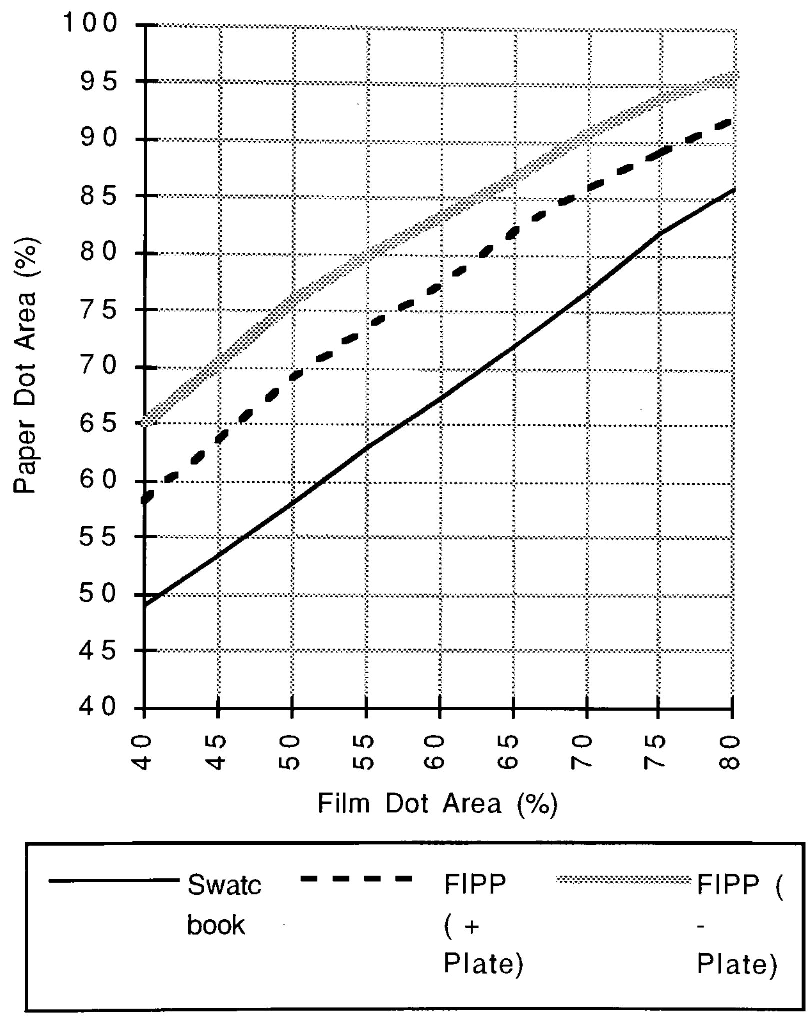


Table 4 shows the paper dot area of the four process colors, as measured from the swatchbooks. Please note that the values were obtained from one swatchbook only, and it is assumed that the swatchbooks produced by Focoltone were printed in a consistent manner. The corresponding plate/press curves are shown in Figure 2.

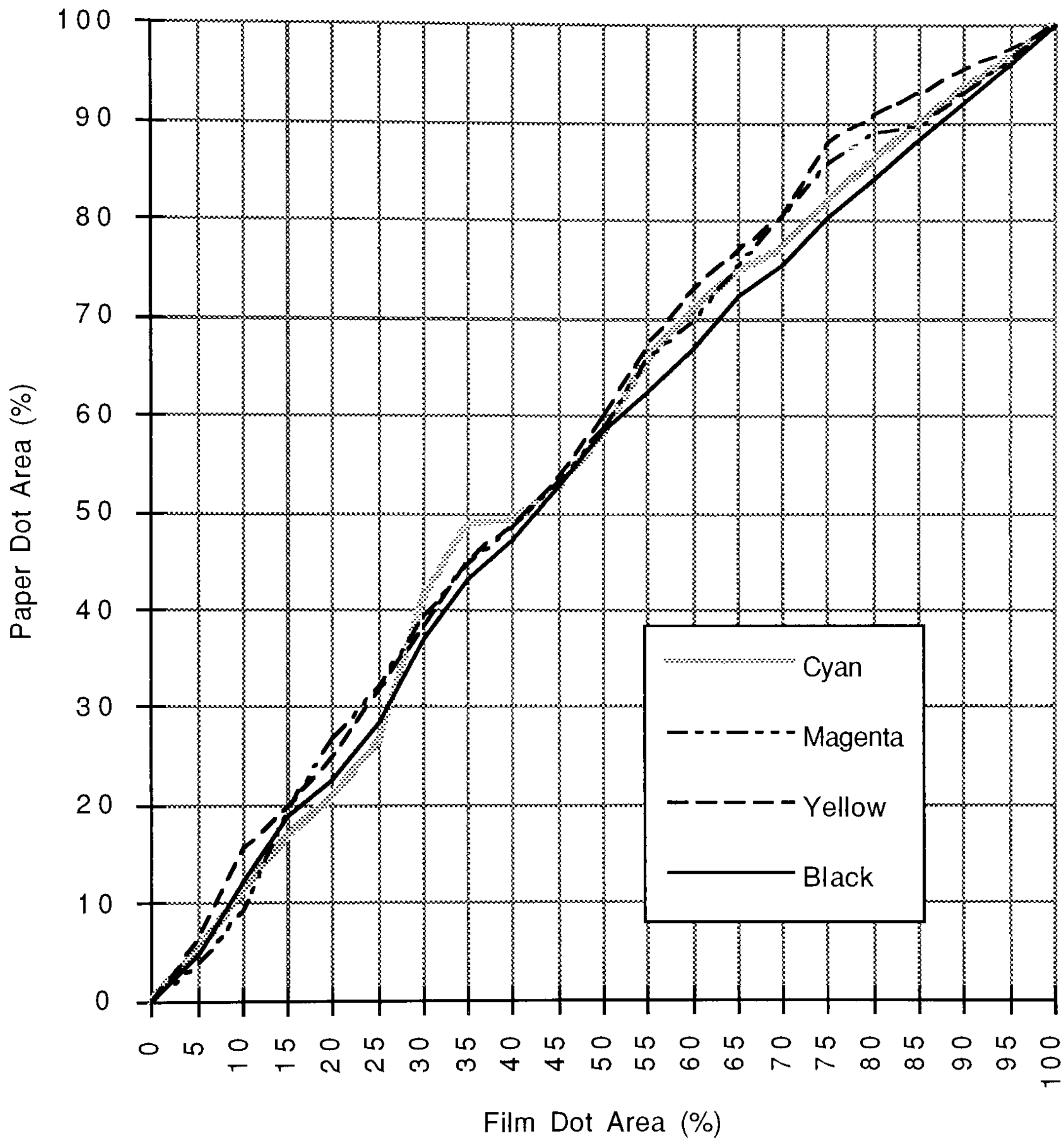
Table 4. Film Tints and Their Corresponding Paper Dots
As Based on Focoltone Swatchbook*

Film Dot Area (%)	Paper Dot Area (%)			
	Cyan	Magenta	Yellow	Black
5	5.1	4.0	6.4	4.7
10	11.1	9.4	15.8	12.2
15	16.8	19.6	20.1	18.9
20	20.7	26.8	25.0	22.7
25	26.3	32.2	32.1	28.4
30	41.1	39.6	38.4	37.2
35	48.8	44.7	45.3	43.3
40	49.1	48.52	48.9	47.1
45	52.6	53.3	53.9	52.7
50	57.9	58.6	60.0	58.4
55	65.6	66.0	67.3	62.4
60	70.9	69.9	73.2	67.0
65	74.6	75.5	77.1	72.4
70	77.1	80.6	80.7	75.5
75	82.0	85.9	88.0	80.4
80	86.1	89.2	90.9	-
85	90.0	89.8	100	-

*Based on Murray-Davies Equation.

It has been shown that the process specifications for printing Focoltone colors, as supplied by Focoltone, are inadequate. However, by obtaining solid ink density and dot area information from the color swatches, solid ink density and paper dot specifications, as derived from the film dot and the plate/press curve, can be obtained. Together with the material specifications,

Figure 2. Plate/Press curve of Focoltone Cyan, Magenta, Yellow, and Black



the information may provide more meaningful aim points in a production press run.

As a summary, the specifications for the Focoltone reference colors should be considered as including these specifications:

1. Ink set with spectral properties conforming to international (American, British, or European) standards
2. Coated paper that does not differ significantly in gloss characteristics from paper used in the Focoltone swatchbook
3. Solid ink density conforming to Focoltone swatch values in Table 1
4. Paper dot that is described by:
   a. The standard film dot specification, and
   b. The plate/press curve derived from the swatchbook (Fig. 2)
5. Ink sequence- CMYK
6. Screen frequency of 150 lpi
7. Ink trap behavior that is characteristic of conventional four-color wet-on-wet lithographic printing

Determining Process Conditions and Characteristics

With a better understanding of what specifications to aim for in printing the Focoltone colors, the next step is to duplicate the reference colors as closely as possible by adhering to properly understood specifications.

Out of the specifications mentioned at the end of the past section, the ink trap and the plate/press curve are factors that cannot be directly controlled (Pobboravsky, 53) . These two factors are determined by prevailing press conditions.

Ink Trap

Ink trap is the transfer of one ink film over an ink film that has been previously printed . Trap is affected by the following factors:

- ink tack- the tack of the earlier-down ink should be higher so that more of the next-down ink being printed is transferred.
- ink film thickness- if the earlier-down ink has higher thickness, the transfer of the ink being printed will be lessened.

- ink temperature- a higher temperature decreases ink tack. The temperature of al l the inks should be maintained at the same level
- time between impressions- the longer the time between successive impressions of ink, the more ink will be trapped.
- ink-water balance- excessive water in the ink causes tack to decrease. This results in lower trap.
- paper absorbency- a highly absorbent paper causes ink tack to increase, allowing more transfer of the next-down ink (Field, Color..., 110).

Plate/Press Curve

The plate/press curve is determined by many factors. The list that follows mentions some of these factors :

- Paper- less dot gain results from smoother paper and paper with more coating.
- Ink- Inks with higher tack and higher pigment concentration exhibit less dot gain.
- Ink film thickness- dot gain increases as ink film increases.
- Impression pressure- dot gain increases as impression pressure, from plate and blanket packing, increases
- offset blanket type- the use of a compressible blanket results in less dot gain, as compared with the use of a conventional blanket
- ink-water balance- when excessive water is mixed in with the ink, a higher dot gain results.
- press speed- when the press is in good mechanical condition and is properly adjusted, dot gain tends to decrease with increased press speed(Field, Color ..., 114-115).

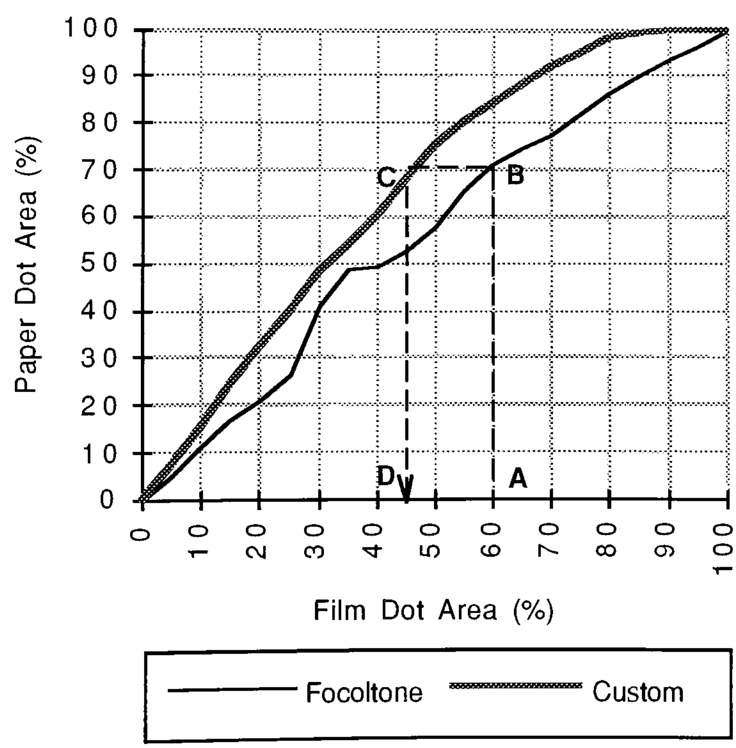
Fingerprint Run

The number of factors affecting the the plate/press and trapping characteristics of a press run underscores the need to control the conditions of a press run.

A fingerprint run is a press run used to obtain the press run's characteristics that correspond to a given set of conditions. The objective is to obtain the 'fingerprint' of the press run, which is a set of press characteristics that is unique to the given press conditions. The plate/press curve is one characteristic that is most important. This characteristic relates to dot gain on press, which affects color variability the most (Leach, 30-32).

Since each plate/press curve is considered unique to its corresponding press condition, it is important to have a set of plate/press curves for the particular press condition, which can be repeatedly and reliably obtained in subsequent press runs. With a reliable set of plate/press curves, film dot specifications can be adjusted to conform to it, so that the paper dot can be reproduced.

Figure 3. Determining Custom Film Dot Area (%)
Using Graphs



The process is visualized in Figure 3. The standard film dot is represented by point A on the x-axis, which is a film dot of 60%, and corresponds to point B on the Focoltone curve. The point on the custom curve that corresponds to point B is point C, which has the same paper dot area as point B. From point C, the corresponding new or custom film dot (point D on the x-axis) is determined, which is 45%.

Defining Press Run Conditions

In obtaining the plate/press curves from the fingerprint run, conditions for the press run have to be defined. These conditions should be defined and patterned after usual working conditions. The following variables comprise the press run condition:

1. Ink set
2. Paper
3. Dampening solution
4. Blanket type
5. Plate type
6. Plate/blanket impression pressure
7. Press
8. Plate exposure
9. Solid Ink Density
10. Temperature
11. Press settings such ink settings and impression speed

An example of press fingerprinting conditions is shown in Table 5 .

Table 5. Sample Fingerprint Conditions

Factor	Conditon
Ink Set	Toyo Ink Mark V ES
Paper	Mead Signature 8# coated paper
Dampening Sol'n	Rosos KSP #10 ASM-3 & RV-1000 mixture KSP sol'n of 4 oz/gal + RV sol'n of 2 oz/gal mixed 50-50 ratio; pH= 3.8, conductivity= 1400
Blanket Type	Reeves 2000 Plus (compressible)
Plate Type	3M Viking
Plate/Blanket Pressure	Total pressure= .0006"(blanket is even with bearers and plate = .0006" above bearer)
Press	Heidelberg 72VP
Plate exposure	Solid 4 on UGRA wedge
Solid Ink Density	Cyan- 1.25; Magenta- 1.30; Yellow- 1.00; Black- 1.65
Ink Sweep Setting*	50 units Cyan; 50 units Magenta; 45 units Yellow; 55 units Black (using Heidelberg CPC console)
Impression Speed	5000 iph
Temperature	75° F

* Obtained after solid ink density targets have been attained.

Obtaining Characteristics of Press Run

A control strip, such as the UGRA Plate Control Wedge 1982, is needed to obtain the plate/press curve of the press run. This control strip includes elements for the measurement of plate exposure, solid ink densities, dot gain, slur, doubling and gray balance. These elements are described in Fogra (2-4).

By printing the UGRA Wedge on all four process colors and obtaining values of paper dot area from the halftone wedge, the plate/press curves of the four process colors can be obtained. The halftone wedge is a set of ten patches, containing tints ranging from 10% to 90%(in 10% increments) and a solid patch. Values of paper dot area are obtained and are plotted to produce the plate/press curve (Fogra, 7).

In determining the plate/press curve, procedures in platemaking must be standardized and implemented. These procedures are discussed in Fogra (10-13). Additionally, the doubling and slur panels in the control strip should not deviate by more than 0.05.

Table 6 shows sample values of paper dot area obtained from the halftone wedge.

These values are used in constructing plate/press curves that are useful in converting Focoltone standard film dot area to film dot area, the dot area being customized to the particular press conditions and characteristics.

Table 6. Sample Values of Paper Dot Area
Obtained From UGRA Halftone Wedge

Film Dot	Paper Dot Area (%)			
Area (%)	Cyan	Magenta	Yellow	Black
10	15	16	18	18
20	32	32	34	33
30	48	47	50	47
40	60	58	63	58
50	75	70	75	68
60	84	79	85	77
70	92	88	94	86
80	98	96	100	94
90	100	100	100	100

REPRODUCING FOCOLTONE COLORS ON PRESS

In reproducing Focoltone colors as accurately as possible, the dot gain from film to paper must be controlled tightly. On the prepress side, it is important to be able to produce the appropriate dot area on film, and be able to reproduce the dot on the plate as faithfully as possible. On the press side, it is important to be able to control the dot gain so that the dot area on paper is close to the desired dot area on print.

Prepress

As illustrated in Figure 3, the standard film dot specification of Focoltone has to be converted to a custom film dot specification, which is suitable for the intended production press run. Similar charts are shown in figures 4a to 4d,

Figure 4a. Cyan Plate/Press Curve, Custom and Focoltone

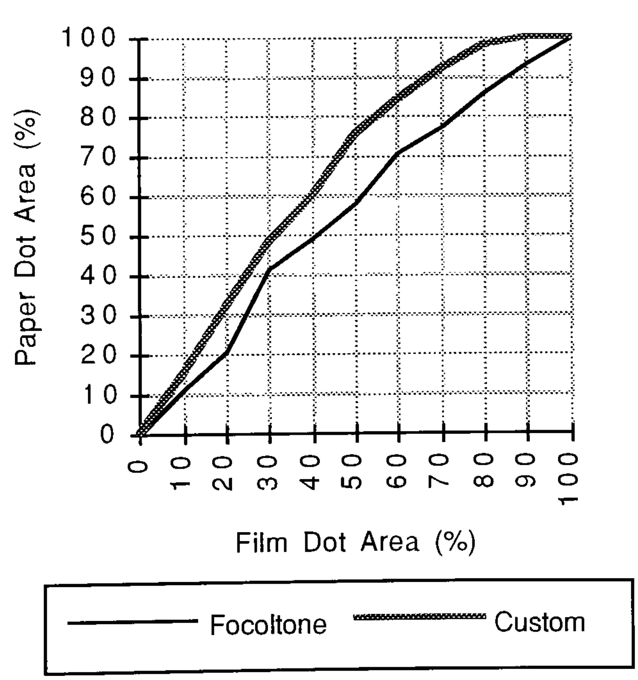


Figure 4b. Magenta Plate/Press Curve, Custom and Focoltone

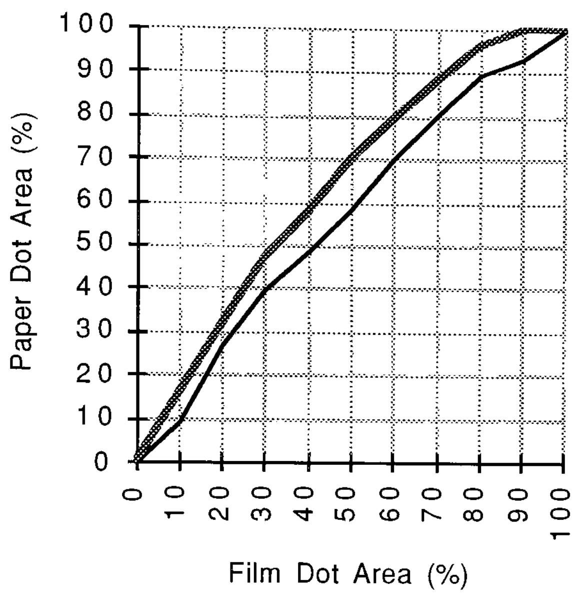


Figure 4c. Yellow Plate/Press Curve, Custom and Focoltone

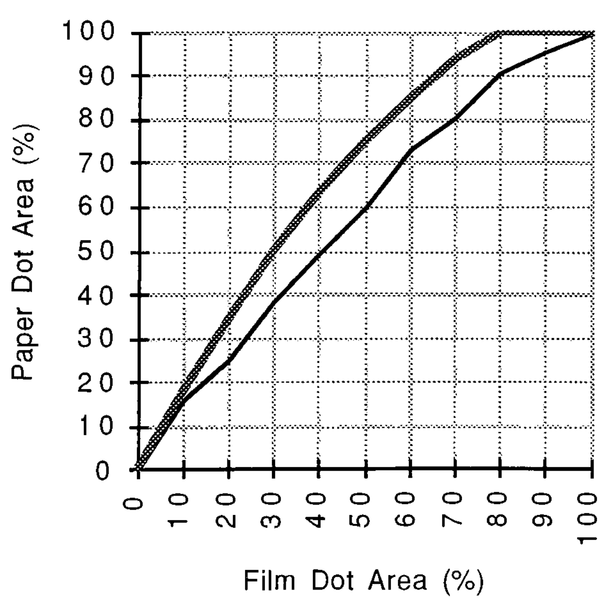
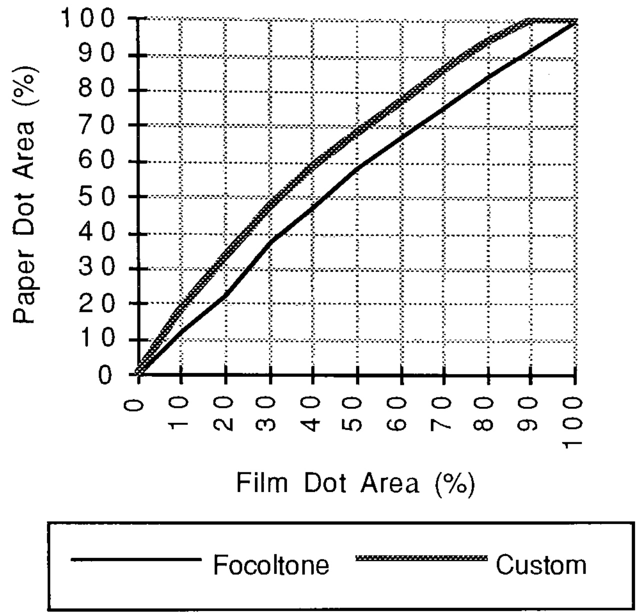


Figure 4d. Black Plate/Press Curve,
Custom and Focoltone



which can be used for the conversion. The charts are based on the Focoltone swatchbook's tonal curve and the sample fingerprint run's tonal curve, as derived from Table 4 and Table 6, respectively.

An example of this conversion process is Focoltone 6048, which has a standard film dot specification of 75% cyan, 75% magenta, and 75% black. Using the procedure described in an earlier section, as illustrated in Figure 3, the custom film dot specification should be 57% cyan, 62% magenta, and 62% black.

The process of conversion can either be done manually, through the use of the above graphs, or can be done by software. Focoltone mentions its dot gain programme as capable of doing the conversion. Also, EFI (Electronics for Imaging, Inc.) provides an Eficolor Profile Editor, which allows the user to describe the press run's plate/press curve. This description, called a printer profile, works in consonance with the Eficolor Extension of QuarkXPress. When outputting separation films of Focoltone colors using QuarkXPress, the conversion of standard film dot to custom film dot takes place automatically. After the separation of films, plates have to be exposed under standardized platemaking procedures, as earlier mentioned.

Press

A strategy of controlling color quality and uniformity is based on maintaining the SIDs of the process inks within tight tolerances. By using a densitometer to monitor the SID from color control bars on the press sheet, color quality can be achieved. Using this strategy of color control, the quality control of ink and paper has to be very strict (Pobboravsky, 53).

Since a set of target SID's have already been determined from the fingerprint run, the press run can begin with less press adjustments. With the use of automated press controls such as the Heidelberg CPC, the need for press adjustments is lessened further, as the CPC console can automatically enable press settings appropriate for particular press runs. This capability comes from a feature of the CPC console that allows press run settings to be saved for future retrieval and use.

While it may be argued that adjustments of SID may be needed to compensate for changes in dot gain and trapping during a press run in order to maintain color hues (Southworth, 3), it has also been observed that variations in SID and dot gain can be minimized when operators in an offset printing process were not allowed to alter press setting during a press run (Compton, 159).

The Heidelberg CPC console enables the printer to monitor, correct, and thus minimize variations in SID. When SID variations are outside tolerance, corrective action on ink settings may be made automatically by the CPC console, to alleviate the situation.

In a study by Gaston (42), with regard to the acceptability of color variation of 3-color overprints, SID variations of Cyan, Magenta, and Yellow, are allowed within these ranges:

Cyan	0.13
Magenta	0.12
Yellow	0.13

Applied to printing Focoltone colors, SID tolerances for CMY would be:

Cyan	1.27 ± .065
Magenta	1.25 ± .06
Yellow	1.00 ± .065

The process capability of presses, in a study by Bain (3), has a standard deviation of SID ranging from .01 to .03, with most having the value of .01. Assuming a 99.7 % confidence level, SID variations would range from ±.03, for presses with good process capabilities, to ±.09, for presses with lesser process capabilities. With the use of good printing presses, it can be seen that a variation of ±.03 falls within tolerance.

Having good process control of SID also allows the press to be run in a condition that allows for desirable dot gain characteristics in the press run, as SID has a significant effect on dot gain behavior.

Other Considerations

While dot area is the most important control variable in color reproduction, other factors that were mentioned in the fingerprint run have to be controlled as well. Since these factors all contribute toward the characteristic behavior of the fingerprint press run, these factors have to be similar in production runs that are patterned after the fingerprint run. In this manner, achieving the desired dot gain characteristics, as shown in the fingerprint run's plate/press curve, is made possible.

V. CONCLUSION

The study of the Focoltone System opens insight into the use of process color-based color communication systems to print synthetic colors. Specifically, the use of these systems entail these procedures:

1. The conversion of standard film dot area specifications into custom film dot specifications
2. The use of controlled procedures in the graphic reproduction process, from the output of film, to exposure on plate, and to the process of printing on paper.

The study questions the statement on the Focoltone booklet which states that Focoltone colors can be reproduced using standard specifications on any normal rotary sheet fed press. According to the booklet, a close match can be easily achieved by adjusting ink density levels and making normal press adjustments. Because the dot gain characteristics of the process used to print the Focoltone swatchbook differ significantly from those of industry average values, the reproduction of color would not be accurate, as dot gain variation has the most significant influence on color reproduction.

Instead, there is a need to understand the process characteristics of the production press. In a fingerprint run, the plate/press curve of the process are obtained. With the plate/press curves of the fingerprint run and of the swatchbook, the standard film dot area can be converted to a custom film dot area. Software such as Focoltone's dot gain programme and the Eficolor

Profile Editor, as used with QuarkXPress and its Eficolor extensions, can facilitate the process of conversion.

The custom film dot should eventually be reproduced on paper to a desirable paper dot area. The dot gain that occurs from film to paper has to be predictable, and thus, there is need for control of the graphic reproduction process, from the film to the paper.

The control of process color printing can be achieved by minimizing process variability from the start, and by use of control mechanisms during the printing process. In minimizing process variability, raw materials and procedures need to be standardized and implemented. The paper, ink, plate, plate exposure, and press settings have to be standardized and strictly followed. During the press run, solid ink density has to be controlled so that the deviation from target settings are minimized.

Because synthetic colors have a uniform tonal background, variations in the printing process are more apparent to observers. This being the case, a proper understanding of process color-based color communication system as it relates to the actual printing process is needed. The print designer/buyer may appreciate the need for a proper selection of print suppliers. Print suppliers who observe good quality control in their print processes, and understand the nature of process color-based color communication systems, can be in a position to print synthetic colors as accurately and consistently as possible.

WORKS CITED

Bain, L. J. Optical Density and Process Control. Graphic Systems Division, Rockwell International Corp., Graphic Systems Division. Chicago. Aug. 1987.

Brehm, Peter V. Introduction to Color Bars: A User's Guide to Color Bar Application. Graphic Communications Association. Alexandria, Virginia. 1992.

Compton, John and Larry Wilson. "The QPC Program and the Practical Application of Statistical Process Control." Taga Journal. 1988.

FIPP (The International Federation of the Periodical Press). Specifications for European Offset Printing of Periodicals. 1988.

Field, Gary G. Color and Its Reproduction. Graphic Arts Technical Foundation. Pittsburgh, 1988.

---"Process Color Printing Control." *Graphic Arts Monthly.* Sep 1991: 75-80.

Fink, Peter. PostScript Screening: Adobe Accurate Screens. Adobe Press. Mountain View, California, 1993.

Flint Ink Corporation. A Quick Reference Guide to Evaluating Print Characteristics. Flink Ink. 1990.

FOGRA. Fogra Praxis Report no. 30, BVD/FOGRA Standardisation of Offset Printing. FOGRA. Munich, West Germany. 1984.

Gaston, John G. III. An Investigation of Solid Ink Density Variation as Determined by the Acceptability of Overprints in Process Color Printing. Master's thesis, Rochester Institute of Technology, 1981.

Hannaford, Steve. "Color Separation on the Desktop. " *Step-By-Step Graphics, Designer's Guide to Using Color Annual Issue.* 1991: 150-157.

Leach, R.H, C. Armstrong, J.F. Brown, M.J. MacKenzie, L. Randall, and H.G. Smith. The Printing Ink Manual. Van Nostrand Reinhold (International) Co. Ltd. Berkshire, England. 1988.

McIlroy, Thad. "Color Matching Systems." *Desktop.* Vol. III No. 5: 39.

Pobboravsky, Irving. Process Color Printing in Newspapers: A Tutorial. Rockwell International Corp., Graphic Systems Division. Cicero, Illinois. 1987.

Stamm, Scott. "An Investigation of Color Tolerance." Taga Proceedings. 1981: 156-173.

Streight, Steven. "Color Communication Systems." *Step-By-Step Graphics, Designer's Guide to Using Color Annual Issue.* 1991: 168-173.

Southworth, Miles. "Controlling Color on a Printing Press." *Quality Control Scanner* Vol. 3 No. 4.

APPENDIX

APPENDIX

Validation of Apparent Dot Area Readings

In obtaining the apparent dot area, the densitometer used the Murray-Davies equation, which restated is:

$$\% \; ADA = (1-10^{-D_t}) / (1-10^{-D_s}) * 100$$

where: D_t = Density of printed target tint minus paper density
D_s = Density of nearest solid patch minus paper density

As seen in the equation, apparent dot area is inversely related to D_S. A lower reading of D_S would result in higher dot area readings. Since the D_S reading was based on the only available solid ink swatch on the swatchbook, the dot area reading might be inaccurate because the D_S should be based on the solid patch nearest to where the tint was printed. But since it is not possible to obtain such a patch, the only available reading had to come from the solid swatch of the swatchbook.

However, it is possible to recalculate the dot area readings to give values that are more conservative. Since Table 2 and Table 3 show large differences in dot gain between Focoltone and FIPP, a conclusion was made that the dot gain characteristics of Focoltone are significantly lower than those of FIPP industry average values.

The dot area obtained from the densitometer would have to be recalculated to favor the argument that challenges that conclusion. Thus, D_S would have to be given lower values, so that the Focoltone dot area would be higher. With a new set of paper dot area values that are higher, a comparison could once again be made to see if these new Focoltone paper dot area values are still significantly lower than those of FIPP industry average values.

The process of recalculating paper dot area values is explained. Rearranging the equation above,

$$D_t = -\log[\,1 \quad \%ADA(1\text{-}10\text{-}D_s)/100]$$

In order to obtain D_t, %ADA and D_s would have to be given. %ADA is the paper dot area, as obtained from Table 3, whereas D_s would be obtained using the formula:

$$D_s = SID - D_p$$

where:

SID = solid ink density (not zeroed on paper, see Table 1)
D_p = density of paper

where: D_{pc} = .048
D_{pm} = .056
D_{py} = .065
D_{pk} = .052 (obtained from swatchbook paper)

With the above data, D_t can be obtained as shown in the Table A1:

Table A1. Calculation of Tint Density

Film Dot Area (%)		%ADA	SID	Dp	Ds(old)	Dt
Cyan	25	26.3	1.27	0.048	1.22	0.1233
	50	57.9	1.27	0.048	1.22	0.3413
	75	82.0	1.27	0.048	1.22	0.6398
Magenta	25	32.2	1.25	0.056	1.19	0.1558
	50	58.6	1.25	0.056	1.19	0.3454
	75	85.9	1.25	0.056	1.19	0.7078
Yellow	25	32.1	1.00	0.065	0.94	0.1449
	50	60.0	1.00	0.065	0.94	0.3282
	75	88.0	1.00	0.065	0.94	0.6532
Black	25	28.4	1.60	0.052	1.55	0.1402
	50	58.4	1.60	0.052	1.55	0.3640
	75	80.4	1.60	0.052	1.55	0.6600

With D_t values obtained, the next step is to obtain $Ds_{(new)}$, which would be used in the original equation to obtain %$ADA_{(new)}$:

$$\% \ ADA_{(new)} = (1-10^{-D_t}) / (1-10^{-D_{s(new)}}) * 100$$

In obtaining $Ds_{(new)}$, a low value of SID is needed. Since .01 is the standard deviation for SID variation in most presses (Bain, 3), SID would deviate in the range of ±.03 for a 99.7% degree of confidence. Thus, the low value would be a value that is -.03 from the SID values obtained from Table 1.

As a result, % $ADA_{(new)}$ would be obtained as shown in Table A2:

Table A2. Recalculation of Apparent Dot Area

Film Dot Area (%)		Dt	SID(new)	Dp	Ds	%ADA(new)
Cyan	25	0.1233	1.24	0.048	1.19	26.42
	50	0.3413	1.24	0.048	1.19	58.17
	75	0.6398	1.24	0.048	1.19	82.38
Magenta	25	0.1558	1.22	0.056	1.16	32.36
	50	0.3454	1.22	0.056	1.16	58.89
	75	0.7078	1.22	0.056	1.16	86.32
Yellow	25	0.1449	0.97	0.065	0.91	32.40
	50	0.3282	0.97	0.065	0.91	60.57
	75	0.6532	0.97	0.065	0.91	88.83
Black	25	0.1402	1.57	0.052	1.52	28.46
	50	0.3640	1.57	0.052	1.52	58.52
	75	0.6600	1.57	0.052	1.52	80.57

Since the new % ADA do not differ significantly from the %ADA reading from the densitomer (see Table A3), the conclusion that the dot gain characteristics of the Focoltone printing process being lower than those of FIPP industry average still holds.

Table A3. Comparison of %ADA (Densitometer Reading vs. Recalculated Values)

Film Dot Area (%)		%ADA (dens.)	%ADA(recalc)
Cyan	25	26.3	26.42
	50	57.9	58.17
	75	82.0	82.38
Magenta	25	32.2	32.36
	50	58.6	58.89
	75	85.9	86.32
Yellow	25	32.1	32.40
	50	60.0	60.57
	75	88.0	88.83
Black	25	28.4	28.46
	50	58.4	58.52
	75	80.4	80.57